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Effects of antisymmetric spin-orbit forces due to three-body nuclear forces using density functional theory

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Density functional theory, widely adopted in nuclear physics, incorporates many-body correlations by expressing the interaction between nucleons constituting a nucleus using a density-dependent Hamiltonian. In addition to two-body nuclear forces, three-body nuclear forces are known to be important in the interaction between nucleons, and density functional theories of the Skyrme and Gogny types have been proposed. The parameters related to the interactions that appear in the density functional are determined to reproduce the typical properties of nuclei, such as radius, density saturation, and mass. However, the strengths of the two-body and three-body nuclear forces used in the above density functional are determined in light of experimental facts about nuclei, and thus do not necessarily embody the actual properties of nuclear forces. Therefore, there have been active attempts to explain the properties of nuclei from realistic interactions. A study of large-scale shell model calculations using nuclear forces obtained from chiral effective field theory has revealed that three-body nuclear forces have a large influence on the spin-orbit splitting produced by spin-orbit forces, and in particular, the contribution of the vector component of three-body nuclear forces, called the antisymmetric spin-orbit force, is dominant. However, the nuclei investigated in this study are mainly limited to light nuclei, and the qualitative effects of three-body nuclear forces on spin-orbit splitting are not yet known for heavy nuclei. The purpose of this study is to formulate the antisymmetric spin-orbit force derived from chiral effective field theory based on density functional theory and to investigate its effect by adding it to the conventional density functional. The Skyrme-Hatree-Fock+BCS method is employed as the density functional to obtain single-particle energies and spin-orbit splittings for tin isotopes, which are medium-heavy nuclei. The results show that the antisymmetric spin-orbit force has the property of decreasing the radius of the nucleus and decreasing the single-particle energy. This is an effect that cannot be produced by the spin-orbit force due to the two-body nuclear force alone.

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